Geological Field Trips in Southern Idaho, Eastern Oregon, and Northern Nevada

Edited by Kathleen M. Haller and Spencer H. Wood

Open-File Report 2004-1222

U.S. Department of the Interior
U.S. Geological Survey

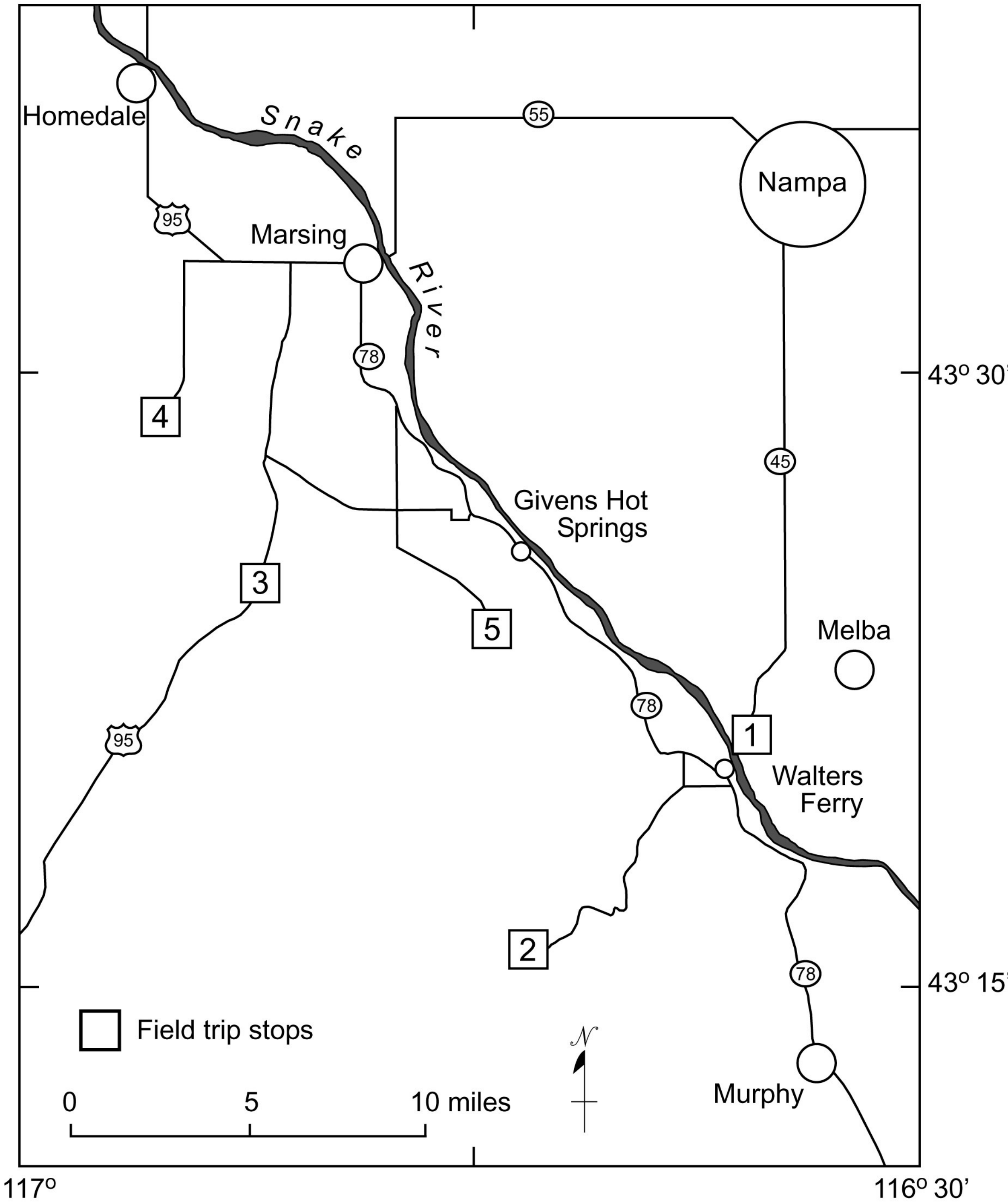

Figure 1. Route map for day 1 and day 2 of this field-trip guide for the Owyhee Front rhyolite field.

Miocene Snake River Plain Rhyolites of the Owyhee Front, Owyhee County, Idaho

By Bill Bonnichsen[1], Mike McCurry[2], and Martha M. Godchaux[1]

Introduction

The rhyolite units of the Owyhee Front are discontinuously exposed along the front for more than 40 km (25 mi) between southwest of Homedale to southwest of Murphy, Idaho. In this field-trip guide, the route to the principal rhyolite units of the Owhyee Front is shown in figure 1. The Owyhee Front region lies along the southwest margin of the western Snake River Plain (fig. 2). From northwest to southeast, the principal rhyolite units are the Jump Creek rhyolite lava-flow field, the Wilson Creek ignimbrite, the Cerro el Otoño dome field, and the Reynolds Creek rhyolite lava flow (fig. 3). This group of rhyolite units seems to have been erupted a short time after the western Snake River Plain graben started to form, and the units range between 11.7 and 10.6 Ma in age. The western Snake River Plain is a complex graben that has evolved over the past 11 or 12 m.y. and seems to be a subsidiary tectonic feature in which northeast-southwest extension accompanied the development of the main Snake River Plain-Yellowstone hot-spot trend (Bonnichsen and others, 1989; McCurry and others, 1997). Starting before the eruption of the Owyhee Front rhyolite units and continuing until about 2 m.y. ago, the western Snake River Plain graben held a large, deep lake generally known as Lake Idaho (Jenks and Bonnichsen, 1989; Wood and Clemens, 2002). It is unknown if this lake was continuously present in the graben, or if it was absent at times.

In the Owyhee Front region the geologic units that are older than the rhyolites of the Owyhee Front are the Cretaceous Silver City Range granitic rocks, the Eocene Rough Mountain felsic volcanics, the Oligocene Salmon Creek volcanics, the Miocene Silver City basaltic, intermediate, and silicic volcanics, the Miocene sediments and tuffs of the Sucker Creek Formation, and the Miocene rhyolitic rocks affiliated with the formation of the Owyhee-Humboldt eruptive center of the Snake River Plain hot-spot track (Ekren and others, 1981; Bonnichsen and Kauffman, 1987; Bonnichsen and Godchaux, 2002). The major rock groups younger than the Owyhee Front rhyolite units include the Miocene, Pliocene, and Pleistocene basalt units associated with the evolution of the western Snake River Plain graben, and Miocene and Pliocene lake and stream sediments of the Poison Creek, Chalk Hills, and Glenns Ferry Formations of the Idaho Group (Ekren and others, 1981; Jenks and Bonnichsen, 1989; McCurry and others, 1997; Bonnichsen and Godchaux, 1998 and 2002).

Rhyolite Units of the Owyhee Front

The Owyhee Front rhyolite units, although erupted within a time window of about a million years, are somewhat diverse in character. The most voluminous group is the lava flows of Jump Creek rhyolite field. These flows erupted from several vents to form a series of partially merged rhyolite lava-flow fields covering the western two-thirds of the Owhyee Front region (fig. 3), west of where any of the Cretaceous granitic rocks are exposed, as mentioned by Godchaux and Bonnichsen (2002). The various Jump Creek rhyolite flows are rich in large phenocrysts, especially plagioclase, and range from the oldest to the youngest rhyolite units known along the front.

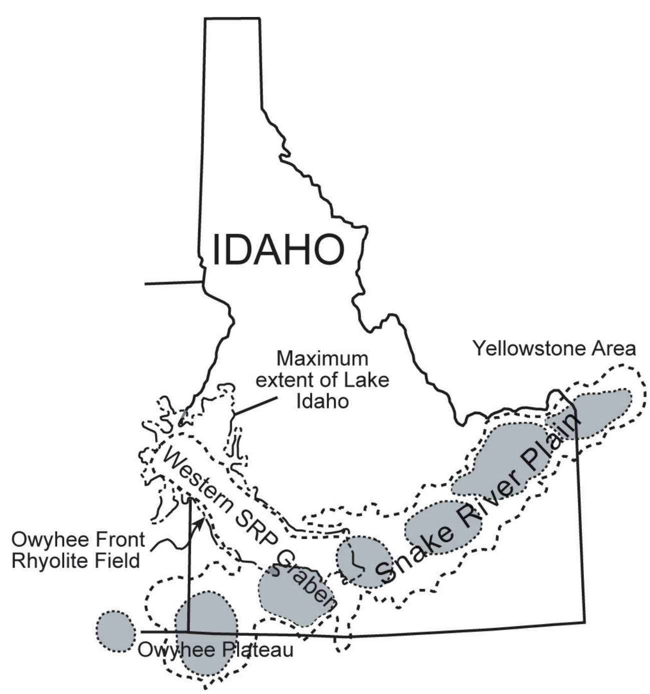

Figure 2. Location of the Owyhee Front rhyolite field in relation to other features of the Snake River Plain volcanic province.

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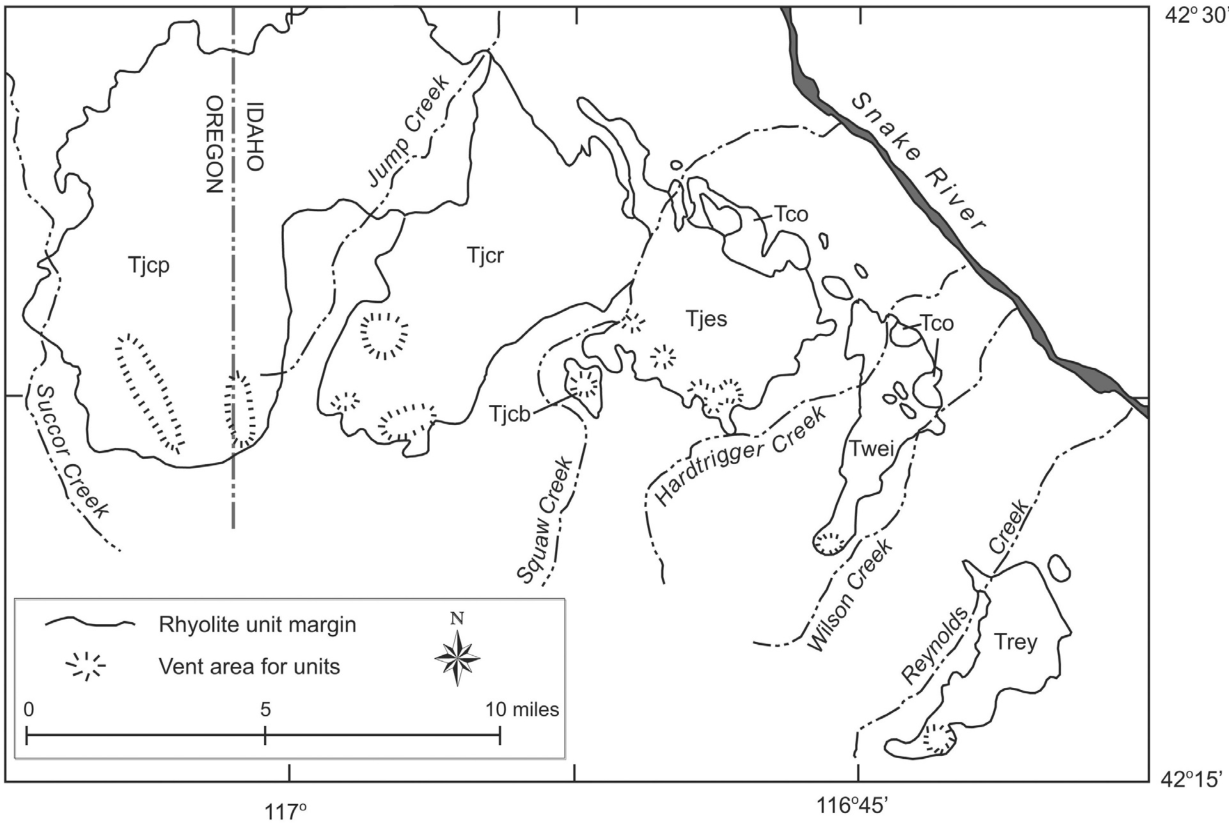

Figure 3. Geologic map outlining the individual rhyolite units in the Owyhee Front rhyolite field of Idaho and Oregon. Symbols used for segments of the Jump Creek rhyolite are: Tjcp—Pole Creek Top segment, Tjcr—Rockville segment, Tjcb—Buck Mountain segment, and Tjcs—Shares Snout segment. Other symbols are: Trey—Reynolds Creek rhyolite lava flow, Twci—Wilson Creek ignimbrite, Tco—Cerro el Otoño dome field.

The other units, the Wilson Creek ignimbrite, the Reynolds Creek rhyolite lava flow, and the Cerro el Otoño dome field, are less voluminous than, and lie east of, the Jump Creek rhyolite field. These eastern units include materials that were erupted as lava flows, ignimbrites, and domes. The phenocryst contents and sizes of these smaller, more easterly units are considerably less than in the flows of the Jump Creek rhyolite, and are dominated by sanidine. Also, the compositions of the eastern units tend toward being high-silica rhyolite, whereas the compositions of the Jump Creek flows tend toward low-silica rhyolite (table 1). Additionally, there are large differences in the minor element contents of these two groups of rhyolite. These differences probably are largely correlative with the differences in phenocryst contents of the two groups of units.

The time interval during which the Owyhee Front rhyolite units were erupted falls within the same time interval that many of the much larger high-grade ignimbrites and rhyolite lava flows were forming in the Bruneau-Jarbidge eruptive center, located to the southeast in the region where the western Snake River Plain merges into the main Snake River Plain hot-spot track (fig. 2). The most voluminous of the rhyolitic ignimbrites erupted from the Bruneau-Jarbidge center in the 12.0 to 10.8 Ma time interval. This is the time interval during which most of the regional collapse associated with the eruption of those huge ignimbrites occurred. Some Bruneau-Jarbidge units, including the earliest ignimbrites, are a little older than the Owyhee Front rhyolite units and others, including most of the rhyolite lava flows, are somewhat younger, but the bulk of the Bruneau-Jarbidge volcanism coincides in time with the Owyhee Front volcanism (Bonnichsen, 1982a, 1982b; Bonnichsen and Citron, 1982; Bonnichsen and Kauffman, 1987; Hart and Aronson, 1983; Armstrong and others, 1980; Perkins and others, 1995; B. Bonnichsen, unpublished data; New Mexico Geochronological Research Laboratory, unpublished reports). Overlap in ages, and similarities in bulk chemical composition and phenocryst mineralogy (*e.g.*, Bonnichsen and Citron, 1982), argues that the origin of the rhyolitic magmas that gave rise to the Owyhee Front rhyolite units, at least in part, may have been related to the same tectonic and magmatic events that gave rise to the silicic magmas that erupted in the Bruneau-Jarbidge region immediately southeast of the western Snake River Plain graben. Conversely, the rhyolite units in the older Owyhee-Humboldt region and younger eastern Snake River Plain region (fig. 2) do not overlap in time with the Owyhee Front rhyolite units.

Table 1. Chemical analyses of Owyhee Front rhyolite samples, southwestern Idaho. Analyses by x-ray fluorescence at Washington State University GeoAnalytical Laboratory.

Sample	1 I-3849	2 I-3747	3 I-3478	4 I-3673	5 I-3846	6 I-3664	7 I-3804	8 I-3672	9 I-3246	10 I-3715
Unit	Jump Ck. Pole Ck. Tp segment	Jump Ck. Rockville segment	Jump Ck. Buck Mtn. segment	Jump Ck. Shares Sn segment	Reynolds Ck. lava flow	Wilson Ck. ignimbrite	Wilson Ck. ignimbrite	Cerro el Otoño Hill 3036	Cerro el Otoño Hill 2471	Cerro el Otoño Hill 2781
Wt.%										
SiO_2	69.82	72.98	69.52	71.77	75.11	77.41	75.37	78.89	77.38	80.49
Al_2O_3	14.28	13.11	14.04	14.05	12.49	12.39	12.32	11.63	11.21	10.64
TiO_2	0.50	0.44	0.48	0.50	0.22	0.10	0.12	0.09	0.09	0.07
FeO	3.53	3.15	3.21	3.17	2.03	0.96	1.45	0.94	0.73	0.72
MnO	0.07	0.07	0.08	0.03	0.01	0.01	0.02	0.01	0.01	0.01
CaO	1.67	1.48	1.80	1.29	0.90	0.26	0.61	0.10	1.13	0.22
MgO	0.63	0.40	0.43	0.21	0.28	0.02	0.33	0.08	0.00	0.07
K_2O	4.34	4.08	4.65	4.71	5.08	5.08	5.55	4.79	4.69	4.28
Na_2O	3.96	3.76	3.89	3.92	3.31	3.71	2.53	3.70	3.80	3.19
P_2O_5	0.13	0.12	0.14	0.14	0.07	0.03	0.05	0.02	0.03	0.02
Total	98.93	99.58	98.24	99.78	99.50	99.96	98.36	100.25	99.06	99.71
ppm										
Ni	7	4	0	4	5	6	11	10	3	6
Cr	0	0	0	0	0	0	0	1	3	0
Sc	8	7	7	4	4	1	3	7	5	3
V	11	21	20	13	33	11	5	0	4	0
Ba	2063	1874	1945	1930	1477	27	71	14	20	15
Rb	87	82	91	97	150	155	150	176	171	143
Sr	290	246	286	227	73	7	36	7	19	10
Zr	558	483	485	517	362	210	213	282	288	172
Y	51	48	49	56	39	39	65	86	72	39
Nb	44	39	41	42	41	55	53	78	74	53
Ga	21	17	22	21	19	20	20	23	26	21
Cu	3	0	1	2	2	0	3	0	0	0
Zn	117	92	103	99	72	65	91	120	35	41
Pb	22	23	26	24	28	29	30	38	16	22
La	89	71	85	82	100	64	68	52	31	89
Ce	164	139	140	134	180	101	127	119	72	100
Th	11	10	18	13	26	14	12	19	7	13

Jump Creek Rhyolite Field

The Jump Creek rhyolite field consists of several lava flows, which erupted from a series of vents that form an east-west elongate zone located several miles south of the margin of the western Snake River Plain graben. The field consists of three principal subdivisions that partially are separated by intervening zones of older rocks. From southeast to northwest these subdivisions are the Shares Snout segment, the Rockville segment, and the Pole Creek Top segment (fig. 3). These segments become larger and younger toward the northwest. In addition, there is the small Buck Mountain segment located just off the southwest margin of the Shares Snout segment. As far as we know, all of the Jump Creek rhyolite was erupted in the form of lava flows. These lavas mainly flowed northeastward from their vents, down the regional slope that existed at that time. At some localities, the flow went over relatively steep ground, perhaps a combination of fault and erosional escarpments, to form zones of large-scale fragmentation and folding. To date, no ignimbrites have been encountered in the Jump Creek rhyolite field, although some spatter accumulations have been found. The zone of vents for the Jump Creek rhyolite field appears to have been on land when the flows were erupted. However, many of the flows ran out into the Miocene version of Lake Idaho, resulting in significant amounts of brecciation and silicification of their more distal parts.

All the flows of the Jump Creek rhyolite field are rich in large phenocrysts, dominated by plagioclase and accompanied by smaller amounts of quartz, alkali feldspar, and pyroxenes. Many plagioclase phenocrysts are more than a centimeter long and some as long as 2 cm have been encountered. Some of the phenocrysts are composite, with alkali feldspar overgrowths on plagioclase, or symplectic intergrowths of feldspars and quartz. Ekren and others (1981, 1984) presented the following petrographic summary for the Jump Creek. Phenocrysts constitute 12–23 percent of the rocks, of which plagioclase (An 33) constitutes 54–88 percent of the phenocrysts, alkali feldspar 0–20 percent, quartz 0–10 percent, ferrohypersthene 6–13 percent, clinopyroxene trace to 4 percent, and traces of zircon, apatite, and olivine. Table 1 presents an analysis from each of the segments of the Jump Creek field. All are quite similar in being relatively low in silica and with quite high contents of Ba, Sr, and Zr, and low Rb, in comparison to samples of the other Owyhee Front rhyolite units.

The Shares Snout segment extends for about 6 km SW.-NE. by about 8 km NW.-SE. and typically ranges from 100- to 200-m thick (fig. 3). Its volume likely is in the range of 3–10 km^3. A sample collected from the Shares Snout vent area gave an Ar-Ar date on sanidine of 11.69±0.06 Ma (New Mexico Geochronological Research Laboratory, unpublished report). Buck Mountain, which probably should be considered as part of the Shares Snout segment, is small in comparison to the other parts of the Jump Creek rhyolite field, with a volume probably in the range of 0.2–0.4 km^3. A sample collected from the Buck Mountain vent gave an Ar-Ar date on sanidine of 11.56±0.25 Ma (New Mexico Geochronological Research Laboratory, unpublished report).

The Rockville segment extends about 12 km SW.-NE. by about 6 km NW.-SE. and typically ranges from 50- to 200-m thick (fig. 3). Its volume likely is in the range of 5–15 km^3. Armstrong and others (1980) give a K-Ar date on sanidine of 11.1±0.2 Ma for a Rockville segment sample.

The Pole Creek Top segment extends about 20 km SW.-NE. by about 10 km NW.-SE. and typically ranges from 100- to nearly 300-m thick (fig. 3). Its volume probably is somewhere in the 20–50 km^3 range. Ferns and others (1993) and Cummings and others (2000) cite a K-Ar date of 10.6±0.3 Ma for a sample from the Pole Creek Top segment.

Reynolds Creek Rhyolite Lava Flow

The Reynolds Creek rhyolite unit (fig. 3) is a lava flow that erupted from a vent along the Owyhee Front and ran northeastward for several kilometers, to where its leading edge entered Lake Idaho. The vent area is in sec. 8, T. 2 S., R. 3 W., and consists of a west-northwest-trending ridge about 0.4-km long that extends across the flow. The flow was erupted into, and appears to have filled, a valley that contained the middle Miocene precursor of Reynolds Creek. The western part of the flow has subsequently been eroded away by Reynolds Creek, as the stream was reestablished near its original course. The Reynolds Creek lava flow is 9- to 10-km long and varies from only about 0.2-km wide at its southwestern end to nearly 4-km wide near its northeastern extent. It varies from less than 50-m to nearly 150-m thick. Its present volume would be in the 2.5–3.5 km^3 range, and its original volume would not have been more than twice that. Thus, it is one of the smallest rhyolite lava flows in the Snake River Plain system, as most contain between 10 and 100 km^3 of material. Throughout most of its length, the Reynolds Creek lava flow consists of fresh rhyolite. Most is devitrified, but at the flow base, and sporadically at the flow top, black vitrophyre is preserved. At the north end of the flow, however, there has been extensive silicification of the Reynolds Creek rhyolite. This, in conjunction with the observation that the flow there has been broken into several large blocks that appear to have been rotated from their original orientations, suggests that the flow ran out into standing water of the Miocene version of Lake Idaho. This is consistent with the nature of several other rhyolite units that were erupted along the Owyhee Front at about the same time (Godchaux and Bonnichsen, 2002).

The Reynolds Creek lava flow erupted at about 11.48±0.09 Ma (sanidine Ar-Ar date, New Mexico Geochrological Research Laboratory, unpublished report), which is in good agreement with an earlier age determination of 11.4±0.6 Ma (sanidine K-Ar date, Armstrong and others, 1980). The Reynolds Creek unit generally contains small sanidine, quartz, and plagioclase phenocrysts, accompanied by traces of pyroxene and zircon. Ekren and others (1981) report 16 percent phenocrysts, in which sanidine constitutes 63 percent, quartz 29 percent, plagioclase 7 percent, and pyroxene pseudomorphs 1 percent, accompanied by traces of zircon. The phenocrysts tend to be larger and more abundant in this unit than in the Wilson Creek or Cerro Otoño units, but not nearly as large or as abundant as in the Jump Creek rhyolite. An analysis of a typical Reynolds Creek sample is given in table 1. This sample indicated the Reynolds Creek to be high in silica, similar to the Wilson Creek and Cerro Otoño units, but to have a Ba, Sr, Rb, and Zr contents in between the Jump Creek and the other units.

As indicated above, we believe the Reynolds Creek rhyolite unit is a lava flow that erupted from a vent area near its southeastern terminus, and it flowed northeastward mainly confined to a paleovalley. Contrary to this view, Ekren and others (1984, p. 41) suggested the Reynolds Creek rhyolite is a welded tuff that had erupted from within the Snake River Plain and flowed southwestward, upslope, away from the Plain, following the paleodrainage. They considered it to be part of a larger welded-tuff unit, which they refer to as the tuff of Browns Creek. Our interpretation that the unit is a lava flow, rather than a welded tuff, precludes it from being part of the tuff of Browns Creek as they describe it, even though the rhyolite constituting the Browns Creek unit is petrographically and geochemically similar to our Reynolds Creek lava flow. Our interpretation is that the Reynolds Creek lava flow is of clastigenic eruptive origin, rather than being an ignimbrite. We believe it was erupted mainly as molten material, perhaps accompanied by some partially solidified rhyolitic lava that was flung into the air at the site of the vent by the force of expanding gasses. These molten fragments fell back and coalesced to form lava that flowed many kilometers from the vent. We suggest that this lava flowed as a nonparticulate silicate liquid, rather than as particles enclosed within a gaseous medium.

Fragmentation of the magma as it ascended and erupted was the cause of the clastigenic nature of the eruption of the Reynolds Creek lava flow. We do not know how much of the gas responsible for the fragmentation of the ascending magma was derived from within the magma itself and how much was from water that gained access to the vent area from sources external to magma. Given that the venting of the flow appears to have occurred in a paleodrainage, it may be that some of the gasses responsible for the explosive character of the eruption were derived from surface sources. If so, then it would be reasonable to think of the eruption mechanism of the Reynolds Creek rhyolite to be partially phreatomagmatic in character.

At some localities, in its northern reaches there is a bona fide welded ignimbrite, on the order of 30-m thick, that occurs stratigraphically beneath the Reynolds Creek lava flow. This ignimbrite is petrographically similar to the rhyolite of the overlying lava flow, but it contains abundant lithic and flattened-pumice clasts, especially in its lower part. Neither the areal extent nor the source of this ignimbrite has been determined. It appears to be quite limited in its distribution, however. Its very existence raises the possibility that during the first phase of the Reynolds Creek rhyolite, an authentic ignimbrite was produced. However, the fact remains that most of material that erupted and which gave rise to the Reynolds Creek flow was truly lava and not explosively derived shards and pumice that traveled as an ignimbrite.

Wilson Creek Ignimbrite

The Wilson Creek ignimbrite extends about 9 km SW.-NE. from its vent area at Wilson Bluff at the southwest end of its flow field down into the western Snake River Plain graben and varies in width considerably. It has a probable volume somewhere in the range of 2–4 km^3. Its vent area apparently was on land but evidently within a palaeodrainage, whereas the distal parts of the unit appear to have been emplaced subaqueously. Contrary to our view, Ekren and others (1984, p. 40) suggested that the source of Wilson Creek unit was in the Snake River Plain and that it flowed southwestward up a paleodrainage and eventually filled it. However, we find the field evidence at the southwestern end of the unit to be so compelling that we believe Wilson Bluff is the vent and that the unit flowed northeastward down the paleodrainage, not southwestward.

The Wilson Creek ignimbrite is a very complex unit, showing wide variation in the nature of materials it contains. There generally seem to be four types of material, probably deposited as a magmatic eruptive time sequence, rather than lateral facies, although it is not yet clear if all of these lithotypes stem from the same eruptive sequence from the Wilson Bluff vent. The oldest deposits are a block and ash mixture with mainly vitrophyric blocks ranging to more than a meter across in a vitric-ash matrix. The next oldest materials are low- to middle-grade ignimbrites that, in places, contain significant amounts of pumice and vesicular vitrophyre clasts. These materials grade upwards and toward the core of the unit to densely welded and devitrified, high-grade rheomorphic ignimbrite with a general lack of lithic inclusions or flattened pumices, and with abundant incipient to large lithophysal cavities. These dense devitrified materials probably were deposited in the central part of the paleochannel and are of considerable, but unknown thickness, perhaps in excess of 100 m. It appears that some of the densely welded core material of the Wilson Creek ignimbrite flowed out into the boundary zone along the Owyhee Front-western Snake River Plain graben, which was partially submerged, to form large blocks in the downflow part of the unit, evidently where the material had been emplaced on incompetent sediments in the lake-margin environment. Lastly, in the first couple of miles downflow (northeast) from the vent area, the unit has a greater thickness of material than elsewhere. This shows up as an elongate lump rising 100 m or so higher than the rest of the longitudinal profile of the unit's generally graded upper surface. We have not detected any sort of cooling break (*e.g.,* a vitrophyre or unwelded ash layer) between this material on top of the unit and the high-grade ignimbritic part of the unit beneath it. Although it is speculation at this point, it may be that this lump actually is clastigenic lava rather than high-grade ignimbrite, which represents the final stage of the eruption.

The block and ash deposits and the vesicular vitrophyre inclusions in the low-grade ignimbrite suggest that the formation and then collapse of early domes or spines may have been part of the eruptive sequence. In the lower part of the nonwelded ignimbritic deposits at Wilson Bluff, there are clasts of a variety of older lithologies incorporated in the ignimbrite. Similarly, at higher stratigraphic levels on the bluff there are similar clasts interstratified with the welded ignimbrite. These foreign clasts very likely represent the results of phreatomagmatic explosions that accompanied the early phases of the eruption, as ground water and water in the drainage were heated to steam and blew up the preexisting ground at the eruption site. Finally, along parts of the western margin of the unit there are low-grade ignimbritic materials that have undergone considerable silicification and chloritization; these materials might be portions of the Wilson Creek ignimbrite that were flooded by streamwater while still hot, right after their deposition, or they might be of an earlier age and unrelated to the Wilson Creek unit.

Two Ar-Ar age determinations on sanidines from the Wilson Creek ignimbrite yield dates that are in good agreement. One is 11.42±0.08 Ma for a welded, but non-rheomorphic, ignimbrite from the east side of the unit. The other is 11.34±0.11 Ma for welded ignimbrite from the vent area (New Mexico Geochronological Research Laboratory, unpublished reports). A third Ar-Ar date on sanidine of 11.41±0.05 Ma (New Mexico Geochronological Research Laboratory, unpublished report) from a rhyolite locality (Hill 2597), which might either be part of the Wilson Creek ignimbrite or part of the Cerro el Otoño dome field from within the Snake River Plain, also is in good agreement. The Wilson Creek ignimbrite typically contains only a few percent of small phenocrysts, dominantly sanidine and quartz. Ekren and others (1981) give these data on phenocryst content of the unit: total phenocryst content is 4–5 percent, of which sanidine is 50–68 percent, and quartz is 32–50 percent, and these are accompanied by traces of clinopyroxene and zircon. Two analyzed samples of the Wilson Creek ignimbrite are included in table 1 and show high silica contents and a paucity of Ba and Sr relative to the Jump Creek and Reynolds Creek units, and show lower Zr but higher Rb abundances than in those units. The composition of the Wilson Creek ignimbrite basically is indistinguishable from that of the Cerro el Otoño samples (table 1).

Cerro el Otoño Dome Field

Along the boundary between the Snake River Plain and the Owyhee Front is a series of small rhyolitic bodies that has been referred to as the Cerro el Otoño dome field (fig. 3). The Cerro el Otoño dome field appears to extend along the margin of the Owyhee Front for 11–13 km (7–8 mi). All of these bodies are small, with dimensions typically in the tens to hundreds of meters, and the volume of the entire field likely is to add up to less than a cubic kilometer of rhyolite. Most of the bodies show considerable silicification suggesting they were intruded and extruded into a lake-margin environment. Some of them have sheared to peperitic margins, evidently formed where viscous lava or magma pushed up through wet sediments, and spatter accumulations have been found at their margins. Locally, some have incorporated bits of sediment, mainly sandstone, near their margins as they were intruded or have pushed the overlying sediments up and deformed them into folds. The form of these bodies range from elongate dikes with steep margins, and are wide but short, to layered deposits that have small areal dimensions. These relations indicate that a combination of limited lateral flowage to form tholoids and the accumulation of fragmental material to form spatter rings were involved in the emplacement of these bodies.

The rhyolite of the Cerro el Otoño bodies is essentially the same as that of the Wilson Creek ignimbrite in its phenocryst assemblage and composition (table 1). Consequently, distinguishing between the dikes, domes, and tholoids of the Cerro el Otoño field and the foundered blocks of the Wilson Creek ignimbrite has been difficult; the problem is further compounded by later faulting along the margin of the Owyhee Front. Two Ar-Ar sanidine dates have been obtained from unequivocal Cerro el Otoño localities. These are 11.14±0.03 Ma for Hill 2471 and 11.03±0.07 Ma for Hill 3036 (New Mexico Geochronological Research Laboratory, unpublished reports). The age of the Cerro el Otoño dome field may be younger than that of the Wilson Creek ignimbrite or, with the 11.41-Ma date cited above for Hill 2597 (which either is part of the Cerro el Otoño dome field or part of the Wilson Creek ignimbrite), it is possible the age of the dome field overlaps the time of emplacement for the Wilson Creek ignimbrite.

The largest rhyolite body in the Cerro el Otoño dome field is the Cerro el Otoño body itself, located at Hill 3036, mainly in sec. 30, T. 1 N., R. 3 W. This body consists of an early-formed spatter ring filled with a small dome or tholoid of rhyolite that filled the crater, which formed during the eruption of the spatter. Most of the spatter was deposited on the inner wall of the crater, but more distal, thinner and outward-dipping beds of spatter also occur as erosional remnants as much as a few hundred meters from the main deposits. The Cerro el Otoño spatter and dome complex measures about 1 km E.-W. and about 0.8 km N.-S. and has a minimum volume of about 0.2 km^3. Its northeastern part has been downfaulted to a position too deep to be observed, so the total extent and volume of this body are unknown. The eruption of the Cerro el Otoño spatter and dome complex, like that of the other bodies in the dome field, seems to have been a combination of magmatic extrusion of quite viscous rhyolite to form the dike, dome, and tholoid forms, and fragmentation of some lavas, by some combination of magmatic and phreatic processes, to form the spatter accumulations.

Road Log and Stop Descriptions

The following 2-day field trip has been designed to bring participants to instructive places in each of the major rhyolite units in the Owyhee Front region and to demonstrate the nature of some of the rhyolite vents, ignimbrites, clastigenic lavas, spatter deposits, and domes that have been produced by the various magmatic and phreatomagmatic eruptions that shaped the Owyhee Front rhyolite field.

General Plan

On Day 1, drive from Boise to Walters Ferry for an overview of the Owyhee Front at Stop 1. Then drive to the vent area of the Reynolds Creek rhyolite, which will be Stop 2. After this, drive to Givens Hot Springs for lunch. After lunch, drive to the French John Hill area to inspect various features of the Jump Creek rhyolite, which will be Stop 3. Then return to Boise via Marsing and Nampa. The road log for Day 1 starts at Walters Ferry and ends at the intersection of Highways 95 and 55, two miles west of Marsing.

On Day 2, drive from Boise through Nampa and Marsing to the junction of Highways 95 and 55. Drive west and south on rural roads to the Jump Creek Falls Park area for Stop 4 to examine the silicification and brecciation that affected the Jump Creek lava flows when they ran into water impounded in an early stage of Lake Idaho. Then return to Highway 95 and follow it east and south to Sommercamp Road. Follow Sommercamp Road east, then Clark Road south, and finally the unimproved powerline access road southeastward to the mouth of Hardtrigger Creek canyon for Stop 5, which will be a tour of the Wilson Creek lava-like ignimbrite and the Cerro el Otoño dome and spatter ring. Return to Marsing via Clark Road and Highway 78, then on to Boise via Highways 55 and I-84. The road log for Day 2 starts at the junction of Highways 95 and 55, 2 mi west of Marsing where the Day 1 road log stopped, and ends at Marsing.

First Day

Mileage Cum.	Inc.	
0.0	0.0	Start trip at intersection of 3rd Street and 12th Avenue in downtown Nampa. Drive southwest on Highway 45, headed for Murphy.
17.5	17.5	Stop 1 at parking lot of Dan's Ferry Service on Highway 45 at the community of Walters Ferry.

Stop 1. View of Owyhee Front and Other Nearby Geologic Features

From the parking lot of Dan's Ferry Service on Highway 45 at the community of Walters Ferry, just north of the Snake River (Walters Butte 7.5-minute quadrangle), good views of the Owyhee Front can be seen. From southeast to northwest, some of the prominent features that can be seen on the southwestern skyline are Hayden Peak in the Silver City Range, the northeast end of the Reynolds Creek rhyolite lava flow, and Soldier Cap Butte and Wilson Peak that are made of granitic rocks overlain by the lower basalt of the Silver City volcanics.

In the immediate vicinity of Walters Ferry are the Hat Butte ferrobasalt, which forms the canyon rim to the north; the Grouch Drain maar that cuts the Hat Butte ferrobasalt near the top of the grade where Highway 45 starts down into the Snake River Valley; the Glenns Ferry Formation lake beds deposited during the latter life of Lake Idaho; and the Bonneville Flood deposits that include the gravel deposits immediately north of Dan's Ferry Service, as well as the rounded basalt boulders scattered through the fields along the southwest side of the Snake River. These and other volcanic and sedimentary units in the Walters Ferry region, are described on the geologic map of Bonnichsen and Godchaux (1998).

Mileage Cum.	Inc.	
		Drive south from Stop 1, across the Snake River, on Highway 45. Once across the river veer left at the road fork onto Highway 78, toward Murphy.
19.0	1.5	Turn onto Reynolds Creek Road and continue generally southwestward.
28.6	9.6	Park alongside the road at the mouth of the unnamed box canyon for Stop 2.

Stop 2. Vent Area of Reynolds Creek Rhyolite Lava Flow

(sec. 8, T. 2 S., R. 3 W.; Wilson Peak 7.5-minute quadrangle)

Walk about 0.3 mi west of the road into the little box canyon, then climb up the back of the canyon to the rim. Later, walk another 0.4 mi westward to the west side of the Reynolds Creek lava flow to look into the canyon of Reynolds Creek. Examine the features of interest (Stops 2A, 2B, 2C, and 2D) along the walk.

Stop 2A. Dipping Layer of Welded Pyroclastic Rocks Beneath the Lava Flow

Exposed in the slope at the head of the box canyon, downslope from the dike complex on the east side of the vent area, is a moderately dipping layer of welded pyroclastic material a few meters thick (fig. 4). At its base, this layer has a fragmental zone, which suggests that part of the emplacement process involved downslope avalanching of erupted material. The fragmental material is overlain by vitrophyre containing streamlined glassy clasts of the same composition in a layered matrix that originally was of finer grain size (fig. 5). This layer, which might have been deposited from a small debris avalanche of very hot particulate material and enclosed partially molten clasts, is limited in its distribution to the vicinity of the vent area, rather than representing an ignimbrite of large extent. This thin layer may have been a precursor to one of the eruptions that led to the development of the Reynolds Creek lava flow, or it may be material that was expelled from a portion of the flow after it had been erupted, perhaps by steam explosions. We don't know if this pyroclastic layer formed at the beginning or the eruption sequence, or sometime later during the development of the lava flow.

Stop 2B. Complex of Near-Vertical Feeder Dikes at East End of Vent Area

Exposed near the canyon rim at the head of the box canyon are a series of parallel rhyolite dikes that form the east end of the vent area of the Reynolds Creek rhyolite lava flow. These dikes generally trend east-west and are as much as a few meters thick (fig. 6). Some are composed of vitrophyre, and others have been partly to completely devitrified. They tend to be subparallel and may be a series of feeder zones through which lava was expelled as the flow developed. Scattered about in the vent area are accumulations of rhyolite that have a fragmental texture. These accumulations are considered to have accumulated by the coalescence of individual blobs of rhyolitic spatter that vary in size from a millimeter to several centimeters across that were thrown into the air during the eruption. In some instances, the individual spatter clots are quite distinguishable and only seem to have undergone flattening (fig. 7). In other instances, the blobs have merged

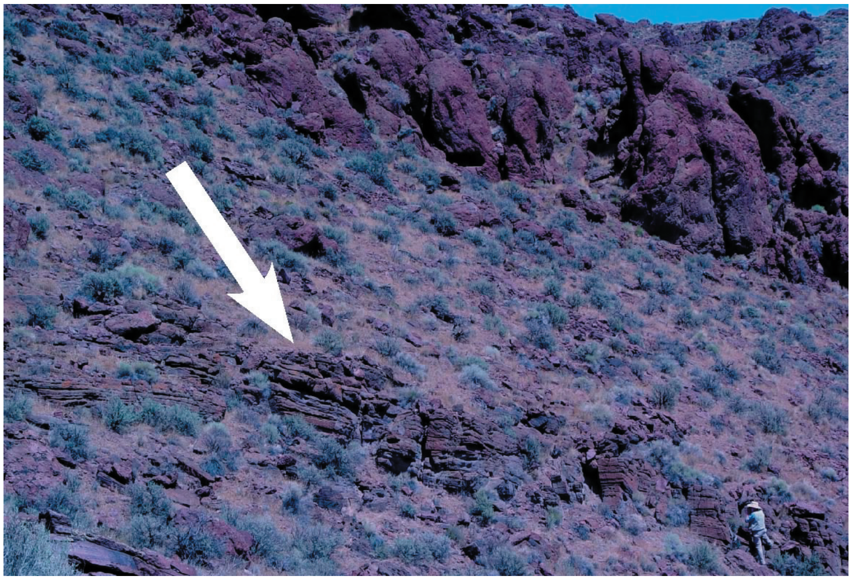

Figure 4. Dipping layer of welded pyroclastic material (arrow) beneath rhyolitic lava and spatter accumulations in the vent area of the Reynolds Creek rhyolite lava flow.

and undergone mass flowage to produce inclined layers of flow-layered and folded rhyolite with abundant secondary gas cavities (fig. 8).

The presence of these preserved spatter accumulations may indicate that substantial amounts, if not basically all, of the material that coalesced and flowed away from the vent to form the rhyolite lava flow erupted as particles or clots of lava, rather than simply welling up and out of the feeder dikes as a nondisrupted flow of liquid silicate melt. If so, then the rhyolite flow should be considered as having a clastigenic mode of eruption, perhaps similar to many basalt flows that have been shown to coalesce from clots of liquid basalt thrown into the air in vent areas, sometimes in the form of spectacular fire fountains. In the case of the Reynolds Creek rhyolite eruption, however, we don't at this time know how high the material may have been thrown from the vent. Nor do we know to what extent the explosive character was the result of the expansion of original gasses in the magma, rather than the result of surface waters that might have been incorporated into the magma or lava and then expanded to steam causing phreatomagmatic explosions that hurled some of the rhyolitic lava about.

Stop 2C. View Point into Reynolds Creek Canyon at West End of Vent Area

After walking along the top of the vent area, which is the ridge proceeding west-northwest from the dike complex of Stop 2B, you will come to the western side of the Reynolds Creek lava flow. This ridge extending across the flow is thought to be the general area from which the Reynolds Creek lava erupted and was the highest part of the flow at that time. This lava evidently filled a paleocanyon, with most of the material flowing northward as much as about 8 km (5 mi) toward the lake that occupied the incipient western Snake River Plain graben. A small amount of the lava flowed westward about 2 km (1.2 mi) to fill the paleocanyon as far upstream as the lava would flow. The western side of the flow seems to have been eroded back some from its original extent by downcutting of Reynolds Creek to form the 350-m-deep (1200-ft-deep) canyon. Across the canyon, the rocks are granite. The rocks below the Reynolds Creek rhyolite lava flow on this (east) side of the stream may be part of the lower basalt of the Silver City area (unit Tlb of Ekren and others, 1981) or part of the older Salmon Creek volcanics.

Stop 2D: Flow Ridges on Top of Reynolds Creek Flow

On the way back to the east side of the vent area turn to the north, where several flow ridges (ogives) are preserved at the top of the lava flow. Their curvature, convex away from the proposed vent area, is consistent with flowage to the north, away from the dikes. The exact origin of these ridges is not

Figure 5. Close-up view of the welded pyroclastic layer shown in Figure 4. Note the dark-colored, glassy lensoidal structures (arrow). They probably are flattened lava clots rather than pumices.

known. They might simply be folds in the upper few meters of the lava flow. However, it is possible that they are ramped-up zones that formed in the rigid top of the flow, or they might have been formed some other way. It would take examination of the third dimension to obtain a clearer picture of their character and origin.

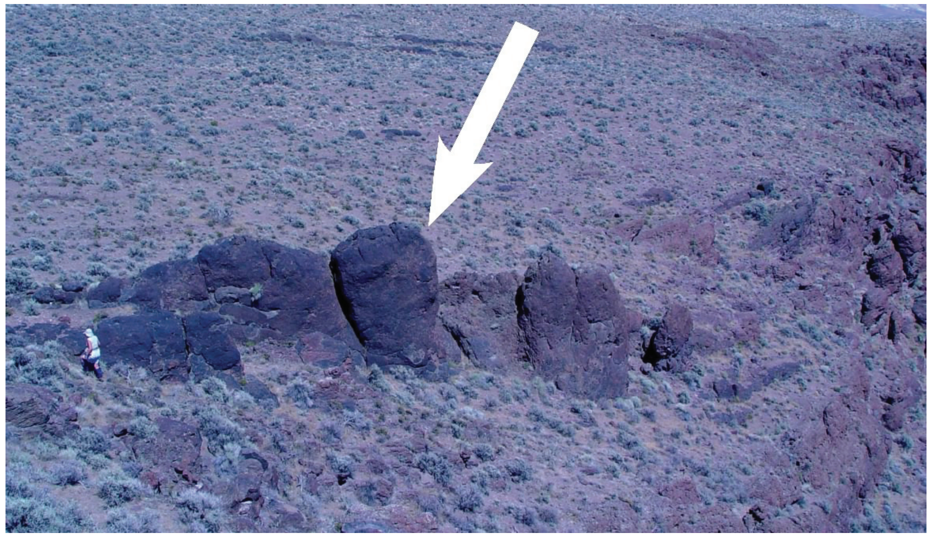

Figure 6. Vertical dike of glassy, somewhat fragmental, rhyolite in the vent area of the Reynolds Creek rhyolite lava flow (arrow).

Mileage Cum.	Inc.	
		When finished at Stop 2, return to the vehicles and retrace the route northeastward on Reynolds Creek Road.
32.9	4.3	View of an unnamed welded ignimbrite that occurs beneath the Reynolds Creek rhyolite lava flow exposed on the west (left) side of the road.
36.9	4.0	Turn north (left) at intersection onto the unnamed road and proceed north, past the defunct ostrich ranch, to join Highway 78.
37.9	1.0	Highway 78. Turn northwest (left) onto the highway and proceed to Givens Hot Springs.
45.0	7.1	Givens Hot Springs natatorium and picnic grounds, a good place to stop for lunch. Afterwards, continue driving northwestward on Highway 78 to its intersection with Sommercamp Road.
48.1	3.1	Sommercamp Road intersection. Turn southward (left) onto Sommercamp Road, and follow it through its turns then westward to its junction with Highway 95.
55.1	7.0	Junction with Highway 95. Turn south (left) onto the highway.
59.5	4.4	Pull off road at the Owyhee Country scenic view turnout and park for Stop 3.

Stop 3. Emplacement and Deformation of Jump Creek Rhyolite Lava Flows in French John Hill Area along Highway 95 and View of Buck Mountain Volcano

(sec. 19, T. 1 N., R. 4 W.; Opalene Gulch 7.5-minute quadrangle)

The various points of interest here (Stops 3A, 3B, 3C, and 3D) can be reached by first walking east of the highway to the overview into the canyon of Squaw Creek, then to the long road cut north of the Owyhee Country viewpoint parking area, then to the other big road cut southwest of the parking area, and finally to the viewpoint farther southwest along the highway for an excellent view of the Buck Mountain volcano.

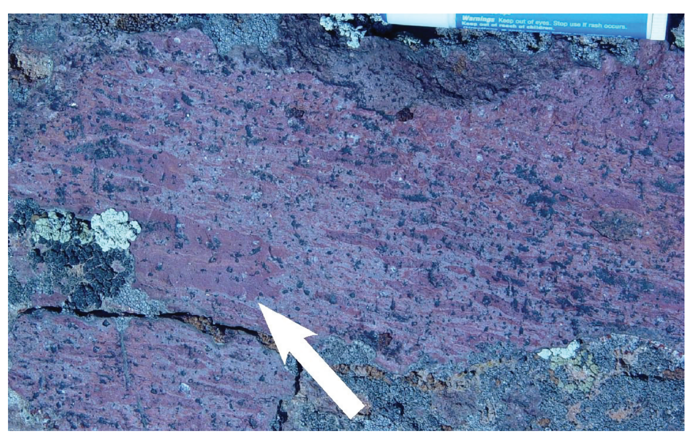

Figure 7. Flattened millimeter- to centimeter-sized spatter blobs (arrow) in the vent area of the Reynolds Creek rhyolite lava flow.

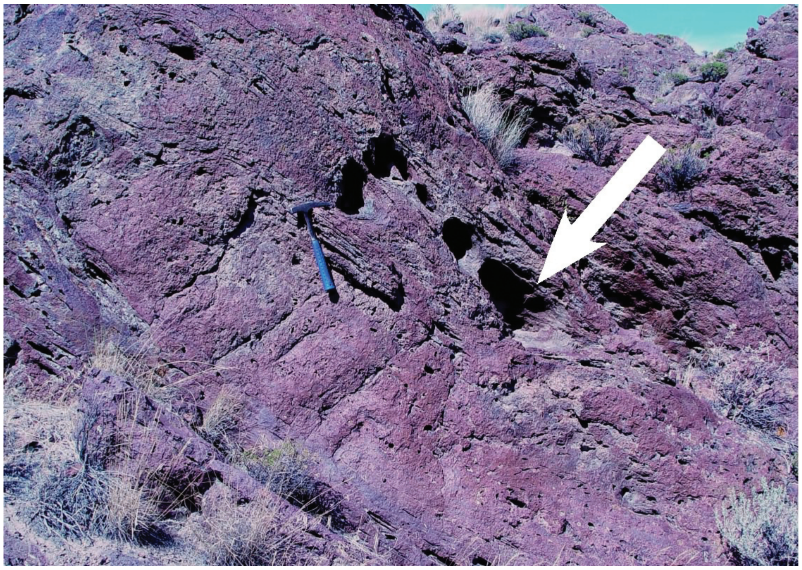

Figure 8. Spatter that merged, flowed, and became folded as it accumulated in the vent area of the Reynolds Creek rhyolite lava flow. Note the large gas cavities that are associated with the hinge zones of the folds (arrow).

Stop 3A: Boundary Zone Between the Rockville and Shares Snout Segments of the Jump Creek Rhyolite Field in Squaw Creek Canyon

The features in Squaw Creek canyon include the eastern margin of the Rockville segment of the Jump Creek rhyolite field, which generally is exposed along the west side of the canyon, and the western margin of the Shares Snout segment, which generally is exposed along the east side of the canyon. The paleo-Squaw Creek drainage evidently was established along the zone where these two segments of the Jump Creek rhyolite field abutted, and then the stream incised along that course. On the east side of Squaw Creek canyon, a little upstream from this viewpoint, is one of the probable vents of the Shares Snout segment. Exposed beneath the Jump Creek rhyolite are sediment and volcanic ash beds of the Sucker Creek Formation.

Stop 3B: Strongly Fractured Rhyolite Along Highway North of Owyhee Country Viewpoint

Walk along the highway north of the viewpoint and examine the walls of the long road cut. The rhyolite here is part of the Rockville segment and appears to be part of the devitrified interior of the unit. The rhyolite is pervasively fractured, with many joints having a vertical orientation, and a lesser number having subhorizontal or inclined orientations. Several near-vertical faults cut this mass of rhyolite, and at one locality a kink-band structure (fig. 9) can be seen to have developed in the near vertical joints. It is our interpretation that most of the joints, especially the abundant near-vertical ones, formed in this rhyolite mass after it had been crystallized and partly to completely cooled but still during the emplacement episode of the flow. The high concentration of near-vertical joints cutting the rhyolite here is unusual for a Snake River Plain rhyolite unit and probably suggests some special structural circumstances during the emplacement of this unit, or shortly afterwards. Relations we will examined in the road cut along the highway to the south (Stop 3C) may provide some insight as to why this rhyolite is so fractured.

Stop 3C: Chaotic Megabreccia Zone in Rhyolite Along Highway South of Owyhee Country Viewpoint

Walk along the highway south of the Owyhee Country viewpoint through the quarter-mile-long road cut in the lower part of the Rockville segment of the Jump Creek rhyolite and what evidently were sediment beds beneath the rhyolite that have been extremely disrupted (fig. 10). This occurrence rightfully can be referred to as a chaotic megabreccia, a non-genetic term for

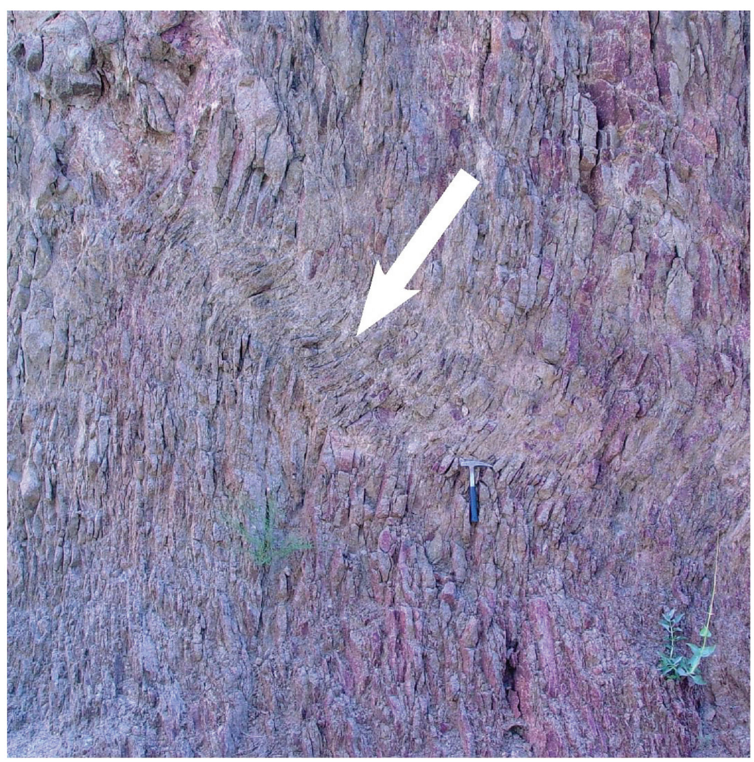

Figure 9. A kink-band zone (arrow) that occurs in a pervasively jointed exposure of devitrified Jump Creek rhyolite along U.S. Highway 95 in the French John Hill area.

Figure 10. A chaotic megabreccia that formed where a Jump Creek rhyolite lava flow may have loaded and mixed with the underlying sedimentary beds, exposed along U.S. Highway 95 in the French John Hill area.

this messy mixture of rhyolite and disrupted sediments. Within this zone much of the rhyolite is vitrophyre that has been fragmented. In some instances, the fragments are intimately mixed with disrupted sedimentary materials. The sediments are a section of fine-grained to cobble-sized materials that initially might have been stream, and perhaps lacustrine, deposits that probably are part of the Sucker Creek Formation or younger deposits eroded and redeposited from that formation. At this locality, these sediments have been thoroughly scrambled and disrupted from their presumed original subhorizontal attitude. Numerous faults cut the sediments and the rhyolite, separating various packages of materials. A plausible interpretation for the origin of this chaotic megabreccia is that this portion of the Rockville segment lava flow cascaded over steep terrain and broke up in the process. It may have flowed into a small paleocanyon along or near the present day position of Squaw Creek. On the slope to the west of this exposure, but out of view from the highway, the lava flow can be seen to steepen in dip as the highway is approached, as if this flow unit plunged into a paleocanyon, supporting the interpretation offered. As the leading edge of the hot, but fragmented, rhyolite filled the paleocanyon it probably loaded the previously deposited, but generally incompetent, package of sediments. This loading probably also disrupted the sediments and caused their upwards diapiric flow into the base of the fragmented rhyolite and the intermixing of the two types of materials. The evidence in this road cut for rhyolite loading of underlying incompetent sediments also may explain the highly fractured rhyolite in the road cut to the north (Stop 3B); it is likely that the rhyolite there was deposited above similar incompetent materials.

Stop 3D. Buck Mountain Volcano

From the highway pullout and parking area south of the chaotic megabreccia road cut one can see, at a distance of about 2.5 km (1.5 mi) due south, a hill named Buck Mountain (fig. 11). Buck Mountain is a small volcano composed of Jump Creek rhyolite, which has been dissected only a little since it formed about 11.56 Ma. The volcano was constructed above deposits of the Salmon Creek volcanics, the Sucker Creek Formation, and the lower basalt of the Silver City area (units

Figure 11. View, looking south from U.S. Highway 95, into the crater area of the Buck Mountain volcano.

Tab, Tsu, and Tlb of Ekren and others, 1981). From this location one can see directly into its breached crater area, where inward-dipping layers of rhyolite are exposed. Examination of the Buck Mountain volcano shows that it consists mainly of stubby lava flows, spatter accumulations, and masses of volcanic breccia. Evidently, lava flows did not extend away from this volcano for distance much greater than its current extent.

Mileage Cum.	Inc.	
		After visiting the points of interest at Stop 3 retrace your route northward on Highway 95 to its junction with Highway 55.
69.7	10.2	Junction of Highways 95 and 55. Day 1 road log ends here. From here, turn east (right) and follow Highways 55 and I-84 back to Boise through Marsing and Nampa.

Second Day

Mileage Cum.	Inc.	
0.0	0.0	Start Day 2 trip at intersection of Highways 95 and 55 where the road log for the first day stopped. Stop in the parking lot at this intersection for a view of the Owyhee Front to the southwest, where the Jump Creek lava flows have been truncated by faulting. Then proceed westward on Highway 95 to where the highway starts curving to the right.
1.9	1.9	Turn left from Highway 95 onto Cemetery Road.
3.1	1.2	Turn left from Cemetery Road onto Jump Creek Road.
6.8	3.7	Sharp turn to the west (right) along Jump Creek Road.
8.3	1.5	Follow Jump Creek road southward to parking lot for Jump Creek Falls Park for Stop 4.

Stop 4. Character of Jump Creek Rhyolite in Vicinity of Jump Creek Falls Park

(sec. 27, T. 2 N., R. 5 W., Jump Creek Canyon 7.5-minute quadrangle)

Much of the Jump Creek rhyolite in this area was emplaced in water and was extensively silicified and brecciated during emplacement. It was subsequently faulted during continued downdropping of the western Snake River Plain graben along the Owyhee Front. The pervasive brecciation and silicification of the rhyolitic lava and other points of interest(Stops 4A, 4B, and 4C) can be seen by first walking south along Jump Creek for 0.2 mi to Jump Creek Falls, and then

Figure 12. View, looking south, of the mouth of Jump Creek Canyon near the margin of the Owyhee Front. Photograph illustrates the massive interior of the Jump Creek rhyolite.

Figure 13. Jump Creek Falls where the stream cascades down a wall of massive devitrified Jump Creek rhyolite.

going to the small sandstone-capped hill located about 0.5 mi north of the park.

Stop 4A. Brecciation and Silicification of Rhyolite along Jump Creek Falls Trail

At the boundary between the Owyhee Front and the western Snake River Plain, which essentially passes through the parking lot of Jump Creek Falls Park, the Jump Creek rhyolite flows are cut off by faults. At the faults, the stream emerges from a deep, narrow canyon cut in rhyolite flows onto a plain, where post-rhyolite lake sediments have been deposited (fig. 12). The Jump Creek lavas along the front have been fragmented and silicified by interaction with the water of the lake. Along the trail between the parking lot and the waterfall, the Jump Creek rhyolite has been broken into large and small fragments. Between the fragments, and commonly cementing them, are veins and masses of secondary silica, mainly chalcedony. The brecciation probably occurred as the rhyolite entered the lake, because it would have flowed down across steep slopes and cooled rapidly by immersion in the lake. The silicification probably represents silica dissolved from the brecciated rhyolite that was reprecipitated in fractures as the rhyolite cooled. At the parking lot, note the sediments exposed along the road. These materials provisionally are assigned to the Chalk Hills Formation and are thought to have been deposited against the front after the Jump Creek rhyolite flows were offset by faults. Downstream from the parking lot, the rhyolite exposed along Jump Creek becomes more and more pervasively brecciated and silicified.

Stop 4B: Jump Creek Falls and Massive Rhyolite in the Lava Flow Interior

At Jump Creek Falls (fig. 13) the rhyolite is not brecciated, although it is pervasively jointed. The style of jointing in the wall of rhyolite at the waterfall is typical of the devitrified interior portions of large rhyolite lava flows. A probable normal fault cuts across the canyon at the site of the waterfall. Several other normal faults, with mainly north-side-down displacements, occur between the waterfall and the parking lot area. The waterfall is slightly greater than 10 m in height.

Mileage Cum.	Inc.	
		When finished at the Park, drive back out of the parking area and proceed to the hill near the road, about one-half mile to the north, for Stop 4C.
8.9	0.6	Stop by the gate in the fence on the east (right) side of road, cross the fence, and walk about 0.1 mi east to the top of the hill.

Stop 4C: Pervasively Fragmented and Silicified Rhyolite and Overlying Sandstone Containing Rhyolite Clasts

At the top of the hill are beds of sandstone that conformably overlie rhyolite (fig. 14). At this locality, the upper part of the rhyolite consists of a mass of small silicified and bleached fragments. The sandstone contains thin interlayers of these fragments and, although the contact between the fragmental rhyolite and the sandstone is abrupt, it would appear to be a transition without a significant time break. Rather, it seems that after the fragmental rhyolite had flowed into its present position the deposition of sand, perhaps representing a near-shore environment in the lake, commenced. This hill may mark the position of a small horst that developed in the Owyhee Front zone prior to deposition of the Chalk Hills Formation sediments and prior to deposition of the sandstone capping the hill. Additional sandstone occurs at the northern base of this hill where the beds are downfaulted.

Mileage Cum.	Inc.	
		After finishing at Stop 4, retrace your route to the junction of Highways 95 and 55.
16.6	7.7	Junction of Highways 95 and 55. Turn south (right) on highway and proceed to the Sommercamp Road junction.
22.4	5.8	Junction of Highway 95 and Sommercamp Road. Turn east (left) on Sommercamp Road.

Figure 14. Sandstone beds lying on the fragmental and altered top of the Jump Creek rhyolite. This part of the rhyolite flow was emplaced subaqueously and the sandstone probably was deposited soon afterwards.

23.2	0.8	The hill to the south (right) is Elephant Butte. It is an outlier of the Shares Snout segment of the Jump Creek rhyolite field preserved either as a slide block or as a remnant of a small horst.
23.7	0.5	The well exposed and slightly deformed sediments to the north (left) as we drive down this grade probably are part of the Chalk Hills Formation of the Idaho Group. These were deposited in Lake Idaho during the latter part of the Miocene. In this region the Chalk Hills Formation sediments overlie outliers of the Owyhee Front rhyolite field and have basaltic ash and subaqueously emplaced basalt flows intercalated within them. The hill south of the road is Hill 3180; it is another outlier of Jump Creek rhyolite of the Shares Snout segment. This rhyolite body is cut by veins of chalcedony and has tilted beds of sandstone lying on its flanks. These sandstones, which we believe belong to the Poison Creek Formation, are older than the Chalk Hills Formation sediments by the road that are noted above.
27.3	3.6	Junction of Sommercamp and Clark Roads. Turn south (right) on Clark Road and follow it south for a mile to where it forks at the powerline.
28.3	1.0	South end of Clark Road where the road forks by the powerline. Take the left fork and follow the unimproved powerline access road generally southeastward for about 3.5 mi to the mouth of Hardtrigger Creek.
29.5	1.2	Pass through a small, northward-plunging anticline that deforms sandstone beds in this area. This sandstone probably is part of the Poison Creek Formation. The anticline may have been uplifted by a still-hidden rhyolite body that punched up from below, but did not reach the surface. The elongation of this anticline is nearly on line with the dike-like rhyolite mass immediately to the northwest (Hill 2597) that was emplaced at 11.41 Ma and which may be either part of the Wilson Creek ignimbrite or part of the Cerro el Otoño dome field.
30.3	0.8	Turnoff from road to the left near the powerline. Look carefully to find this turnoff. Turn sharply to the left on it, rather than proceeding straight.
31.0	0.7	Go through gate and continue southeastward after driving up the short grade.

31.8 0.8 Parking area at the mouth of Hardtrigger Creek canyon, Stop 5.

Stop 5. Rheomorphic Core of the Wilson Creek Ignimbrite and the Cerro El Otoño Spatter and Dome Complex, Lower Canyon of Hardtrigger Creek

(sec. 30, T. 1 N., R. 3 W., Givens Hot Springs 7.5-minute quadrangle)

The parking area at the mouth of Hardtrigger Creek canyon is a good place for lunch. Afterwards, the features of interest can be visited on foot. Walk south for about 0.4 mi along the stream course to see the various facets of the Wilson Creek ignimbrite (Stops 5A and 5B). Then climb up the slope on the east side of the stream course to the base of the cliff, where the spatter ring of the Cerro el Otoño dome (Stop 5C) is exposed above the Wilson Creek unit. Follow this cliff northward about 0.2 mi, then climb up to the top of the dome and walk about 0.5 mi southeastward, across its top (Stop 5D). Then continue to the occurrence of silicified boulders, cobbles, and sandstone on the southeast side of the dome (Stop 5E). After this, follow the southern lower flank of the dome westward to Hardtrigger Creek and follow the stream course northward back to the vehicles, a distance of about a mile.

Stop 5A. Rheomorphic Core of Wilson Creek Ignimbrite

On the walk through the lower canyon of Hardtrigger Creek, an excellent view of the core of this densely welded rheomorphic ignimbrite can be observed. It is somewhat lava-like in many ways due to post-emplacement rheomorphic adjustments. One of the characteristics of the Wilson Creek unit is the presence of lithophysal cavities, some of which are quite large and complex in this area (fig. 15). In this area, it is notable that many of these cavities appear to have been tilted as much as 90 degrees from their original orientations; we attribute this to post-emplacement rheomorphic flowage of the entire rhyolitic mass that forms the core of the ignimbrite. Most commonly, lithophysal cavities such as those in this unit, form with their arched side convex-upwards. Also, note that the rhyolite in this canyon shows well-developed layering. Although some of this layering may be due to flowage during later deformation of the ignimbrite. It also is probable that some of the layering and its small-scale deformation is original and was produced as the flowing ignimbrite made the transition to a continuous mass of silicate liquid that continued to flow, deform, and expel gasses, some of which remained trapped as gas cavities. That is, as the flow underwent progressive aggradation such as described by Branney and Kokelaar (1992, 2002) layering was produced that had a subhorizontal attitude. En masse flowage after progressive aggradation of the entire core of the Wilson Creek unit then tilted and deformed the depositional layering to steep attitudes, as can be observed in the walls of the canyon. The en masse flowage here is not like that in a lava flow where the material may flow many kilometers but is instead of more limited distance. Distances indicated here were just enough to tilt the layering and enclosed lithophysal cavities, which would not require distances of more than a hundred meters.

Stop 5B. Vitrophyre and Breccia at Top of Wilson Creek Ignimbrite

The glassy rocks exposed upstream, about 0.4 mi from the parking area at the mouth of Hardtrigger Creek canyon, vary from dense vitrophyre to perlite and commonly are vesicular. Locally, lithic fragments have been found within this outcrop area. These materials, based on their locations, appear to be a part of the Wilson Creek unit that was rapidly cooled. It probably is part of either the base or the side of the unit.

Stop 5C. Thick Accumulation of Inner-Crater-Wall Spatter at West Side of Cerro el Otoño Dome

The Cerro el Otoño spatter and dome complex sits on the Wilson Creek ignimbrite and is thought to have erupted up through that unit, perhaps through a dike along the northeast side of the complex. The oblique view of the complex taken from the southwest (fig. 16) clearly shows an accumulation of bedded, partially agglutinated, spatter, about 30-m thick (fig. 17), on the west side of the complex, where it is cut by

Figure 15. Lithophysal gas cavities developed in the devitrified, high-grade, rheomorphic core of the Wilson Creek ignimbrite in the lower canyon of Hardtrigger Creek.

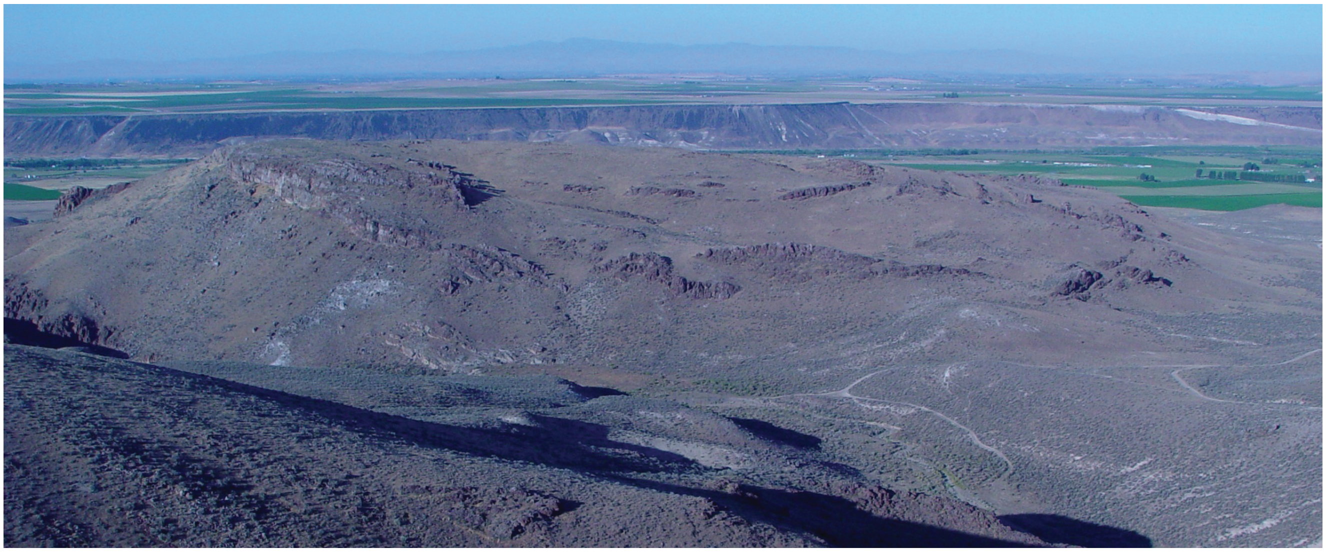

Figure 16. View looking northeast at the Cerro el Otoño dome (Hill 3036). The escarpment on the west side of the dome (left side of view) is an accumulation of rhyolitic spatter. Note the arcuate ridges on the top of the dome.

Figure 17. Dipping rhyolitic spatter layers that were deposited on the inner crater wall of the Cerro el Otoño spatter ring and dome complex.

Hardtrigger Creek canyon. Layering within this spatter dips eastward toward the central part of the complex and is interpreted to have been deposited on the inner wall of a crater. Such inward-dipping spatter deposits occur all around the western, southern, and eastern sides of the complex, but not to the north because a fault has displaced the northern part of the complex beneath the surface. At places, the spatter that accumulated on the inner crater wall appears to have been flowing back into the crater as it solidified. Farther away from the dome, erosional remnants of thinner-layered outer-wall spatter accumulations have been observed.

Notable within the spatter deposits that occur low in the section, on both the west and east sides of the complex, are accumulations as much as a meter thick consisting of small, pea-sized, semispherical drops (fig. 18), many of which have devitrified to reddish-brown spherulites. We refer to these deposits as the “brown pea” horizon and tentatively conclude that the rounded particles were silicate melt drops that, after having been erupted into the air, quenched sufficiently before they landed so that their spherical shapes were preserved. Also, the rate of accumulation would have been sufficiently slow so that the individual drops were not flattened but only sintered together. Microscopic examination of the textural arrangement of the drops (fig. 19) reveals that many had merged into an polygonal equilibrium fabric prior to any devitrification. Others, however, are separated by a glassy matrix, which probably originally was dust. In many, instances the boundaries of the spherulites do not extend all to the way to the drop margins (Godchaux and Bonnichsen, 2002). At present it is not known if the explosive conditions that led to the formation of melt drops, which were quenched in the atmosphere, were due only to the escape of magmatic gasses, or due to meteoric water that gained access to lava in the crater, causing explosive activity that was partially, or wholly,

Figure 18. Layers of devitrified, semispherical spatter droplets that accumulated to form the "brown pea" horizon within the spatter ring portion of the Cerro el Otoño spatter ring and dome complex.

phreatomagmatic in character. The fact that we find the results of such eruptions located in an environment that we believe was at the shore of a large lake, however, leads us to suspect that phreatomagmatic activity played an important part in the origin of the "brown pea" accumulations.

Stop 5D: Traverse Across Top of Cerro el Otoño Dome

In traversing across the top of the dome, you will find that the rhyolite is fairly massive to flow-layered in character and much is devitrified. At many localities, fragmental zones and thoroughly silicified horizons are present in the interior of the dome. Also, as can be seen in figure 16, on the top of the dome is a series of concentric arcuate ridges that are convex toward the southeast. These ridges may be the result of flowage of material from a vent area in the northern part of the dome, or they may be resistant layers of rhyolite that perhaps are more silicified than other parts and represent the sequential accumulation of material as the crater was filled. At several localities in the upper part of the dome, there are thoroughly fragmented silicified zones, which probably represent hydrothermal chimneys that vented high-pressure steam.

Stop 5E. Silicified Sediments Deposited on East Side of Cerro el Otoño Dome

In the southeastern part of the dome, perched high on its side, is a thoroughly silicified sedimentary deposit that evidently was deposited in a stream channel after the dome formed. The deposit has resisted erosion because of its extremely durable character. The deposit grades upwards from rounded boulders and cobbles in its lower part to sandstone in its upper part.

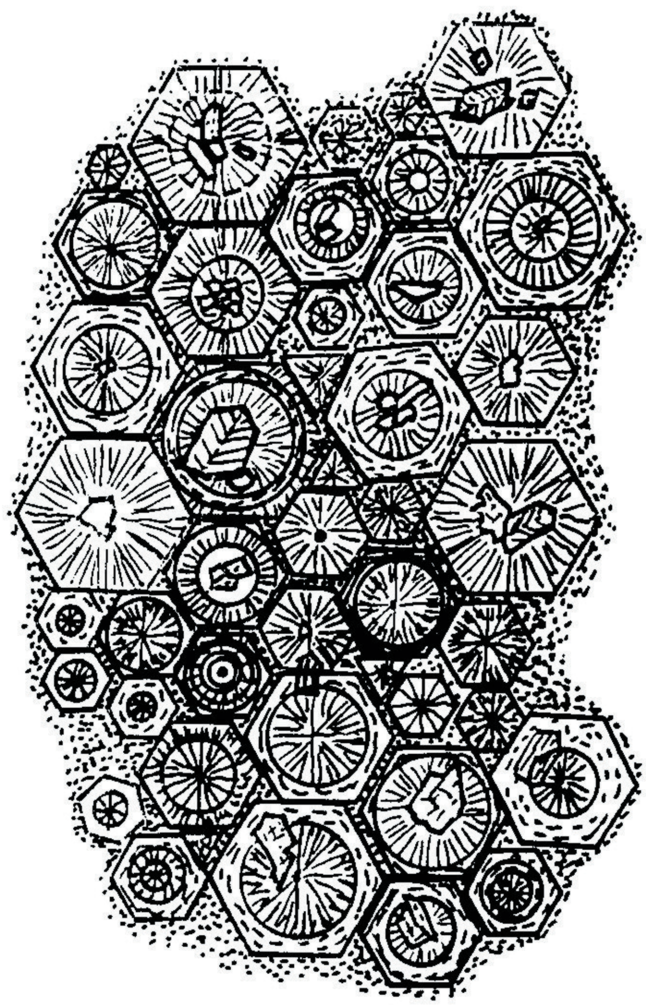

Figure 19. Sketch illustrating annealing and devitrification textures encountered in the "brown pea" horizon of the Cerro el Otoño spatter ring and dome complex. Circles represent spherulites developed in glassy droplets that merged to give an annealed fabric (hexagonal shapes). Stippled areas represent glassy areas that are interstitial to the droplets and may have initially been glassy dust. In the spherulites the radial patterns represent fibrous crystals. Dashed zones outside of the spherulite rims are microperlitic glass that did not devitrify. Small crystals of feldspar, other minerals, and tiny vesicles were present in some of the original droplets and have been enclosed by the spherulites.

Although silicification of the deposit may have occurred while the dome was cooling, it also is possible that it was silicified much later, perhaps coinciding with the emission of hot springs along the Owyhee Front during the episode of faulting and subaqueous basaltic volcanism that occurred in the western Snake River Plain graben 7 to 9 m.y. ago (Bonnichsen and Godchaux, 2002).

Mileage Cum.	Inc.	
		After walking back to the vehicles, retrace your route along the powerline access road to the junction with the south end of Clark Road, follow it north to Highway 78, turn to the northwest (left) on the highway and follow it to the junction with Highway 55 in Marsing.
35.3	3.5	Rejoin Clark Road and drive north.
38.4	3.1	Junction with Highway 78. Turn to the northwest (left).
44.1	5.7	Junction with Highway 55 by the Snake River Market in Marsing. This is the end of the road log for the second day. Turn east (right) on Highway 55 and follow it, via Nampa, back to Boise.

Acknowledgments

We would like to thank all of our colleagues who, while in the field with us, made many helpful suggestions about the nature and origin of the rhyolites that are described in this field guide. In particular we take delight in thanking Craig White, Curtis Manley, John Wolff, Scott Boroughs, Janet Sumner, Mary O'Malley, Spencer Wood, Jocelyn McPhie, and Nancy Riggs. We also would like to thank the institutions that we now or previously worked for, the Idaho Geological Survey at the University of Idaho, the Department of Geosciences at Idaho State University, and the Department of Earth and Environment at Mount Holyoke College, for their support and encouragement over the years. Our thanks for the financial support that funded this research and gave us the knowledge to prepare this guide goes to the Idaho Geological Survey and the STATEMAP program of the U.S. Geological Survey.

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